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Nieminen, Juuso Henrik

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Article

Taking Universal Design Back to Its Roots: Perspectives on Accessibility and Identity in Undergraduate Mathematics

Juuso Henrik Nieminen [1,*] and Henri Valtteri Pesonen [2]

1 Department of Mathematics and Statistics, University of Helsinki, 00014 Helsinki, Finland
2 Faculty of Educational Sciences, University of Helsinki, 00014 Helsinki, Finland; henri.pesonen@helsinki.fi
* Correspondence: juuso.h.nieminen@helsinki.fi

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Abstract: Universal Design has been promoted to address the diversity of learners in higher education. However, rarely have Universal Design implementations been evaluated by listening to the voices of disabled students. For this study, we investigated the perceptions of three disabled students who took part in an undergraduate mathematics course designed with the principles of Universal Design for Learning and Assessment. The study consists of two parts. First, we observed the experiences students had in relation to the accessibility of the course design. The second part consisted of a further analysis of the students identifying processes to understand how they talked about their learning disabilities during the course. Our results highlight many opportunities and challenges that the course offered to the students, whilst also raising concerns about how the students excluded themselves from their student cohort in their identifying narratives. Based on our results, we argue that Universal Design should be returned to its roots by connecting it with the social model of disability. We call for future research to learn from our mistakes and consider the identifying processes of the students while designing, and hopefully co-designing, inclusive learning environments in mathematics.

Keywords: Universal Design; Universal Design for Learning; Universal Design for Assessment; undergraduate mathematics education; the social model of disability; accessibility; identity

1. Introduction

There seems to be a critical silence when undergraduate mathematics education research and disability studies intertwine (see [1]). Lately, there has been a call for a socio-political turn in postsecondary mathematics education [2], but the voice of disabled students is still widely neglected in this field. Tan and Kastberg [3] have argued that in mathematics educational research in general, disabled students are rarely seen as thinkers and doers of mathematics, but rather are seen through their cognitive deficits (see also [4]). For example, Perkin and Croft [5] highlighted issues that dyslexic students of university mathematics might encounter in their studies, including problems with mathematical notation, learning strategies and examination situations. Furthermore, it has been claimed that teaching in undergraduate mathematics education has largely been centred on teacher-driven content delivery through non-interactive lecturing and traditional testing [6–8], which might create challenges for addressing the needs of the diversity of learners with its 'one-size-fits-all' approach. Earlier research has especially suggested that traditional mathematical learning environments are not designed for disabled students, creating barriers to learning [9] and framing students only through their deficits [10]. Little emphasis has been placed on accessible learning environments in the context of undergraduate mathematics—this is a multidisciplinary research gap, the importance of which we are trying to highlight with this study.

In the field of higher education, the concept of Universal Design is often used to promote learning environments that would be accessible to *all* students. In the postsecondary STEM field, Universal Design has been promoted to increase STEM enrolments of underrepresented student groups such as those with disabilities [11,12]. It has been stated that Universal Design would suit mathematical learning environments as well, making it a 'powerful framework to guide learning experiences' [13] (p. 23). While there has been a call for more student-centred learning environments for undergraduate mathematics [6], what is lacking are the perceptions of disabled students in the design processes of these environments—or in the evaluation of them.

The present study introduces a course model reflecting the principles of Universal Design, conducted as part of the Digital Self-Assessment (DISA) project at the University of Helsinki. In the project, an accessible course model for undergraduate mathematics was created. Unlike most of the literature on accessible course designs, we also took assessment into account by replacing the course exam with self-assessment. Based on a large linear algebra course, we were able to measure very high levels of course achievement, deep approaches to learning and self-efficacy [14]. Aligned with earlier studies on the effectiveness of Universal Design models, we could state that our course model was indeed quite effective in terms of course achievement and the quality of study.

However, in this study we observed the perceptions of three disabled students to assess the accessibility of the course model. This study consists of two parts (Studies 1 and 2), conceptualising Universal Design from the viewpoints of both accessibility and identity. Study 1 heard the perceptions of the disabled students as they observed the accessibility of the Universally Designed undergraduate mathematics course. This is followed by Study 2, in which reports on an investigation of how the students build their identities while recreating their experiences of the course in an interview situation. Study 2 supplements Study 1 by taking a different, yet crucial viewpoint on accessibility regarding the identifying processes that Universal Design enables.

2. Study 1: Student Perceptions of Accessibility

2.1. Theoretical Background: Universal Design

Originating from the literature on architecture, Universal Design (UD) refers to accessible design that does not draw on individual adjustments but rather is based on inclusive design for all [15]. This idea has been applied to the field of higher education, and many countries have even introduced the idea of UD in legislation (e.g., [16,17]). UD has been advocated as a model that shifts the view from the *medical model of disability* towards the *social model* [18]. Therefore, UD challenges the common model of offering individual adjustments to disabled students (the medical model), focusing on designing accessible learning environments that support the inclusion of all [19]. Since the social model acknowledges that learning environments create barriers for learning, UD aims to reduce those barriers through a design that acknowledges the diversity of learners.

2.1.1. Universal Design for Learning

In higher education, UD has been applied to many fields such as physical spaces, services and information technology [20]. In the present study, we have limited our focus to the level of individual university courses through the pedagogical framework of Universal Design for Learning (UDL; [20–22]). UDL applies the principles of UD in practice by fostering the social model of disability in the design of learning environments [15,18]. It is not the student who is disabled, but rather, as Gravel and colleagues note, 'it is our learning environments, first and foremost, that are disabled' [21] (p. 99). UDL promotes the idea that accessible learning environments would not be based on individual adjustments (the medical model) but rather on inclusive design, benefiting all students, not only disabled students.

The UDL model has been put into practice through three broad principles that are tied into various networks of the human brain [23]: representation (the 'what' of learning), expression and action (the 'how' of learning), and engagement (the 'why' of learning) [22–24]. Each of these principles has three related guidelines that enable using the framework as a rubric for designing Universally Designed courses; these guidelines are collected into Table 1 (for further details see [23]). The idea is that by applying these principles and guidelines, university courses would address accessibility in many ways, offering students individualised routes for the same learning goals [22]. From this perspective, accessibility is framed through the social model of disability, as the UDL principles ensure that the learning environment itself would not *disable* students.

Table 1. Principles and guidelines of the Universal Design for Learning (UDL) framework [23].

Principle 1: Representation	**Principle 2:** Expression and action	**Principle 3:** Engagement
Guideline 1 Provide options for perception	**Guideline 4** Provide options for physical action	**Guideline 7** Provide options for recruiting interest
Guideline 2 Provide options for language, mathematical expressions and symbols	**Guideline 5** Provide options for expression and communication	**Guideline 8** Provide options for sustaining effort and persistence
Guideline 3 Provide options for comprehension	**Guideline 6** Provide options for executive functions	**Guideline 9** Provide options for self-regulation

2.1.2. Universal Design for Assessment

Studies regarding UD in higher education often concentrate on instruction, while inclusive assessment practices have received less attention. Since assessment has repeatedly been shown to be a major factor in student learning and study in higher education (see [25]), it is crucial to promote accessibility in terms of assessment. Furthermore, the context of university mathematics often means large classroom sizes; universal approaches seem more suitable for courses with 500 students than the option of individual adjustments. Therefore, we have introduced the concept of Universal Design for Assessment to frame accessibility in the field of assessment (UDA; [26,27]). UDA can be defined as 'an integrated system with a broad spectrum of possible supports so as to provide the best environment in which to capture student knowledge and skills' [27] (p. 5). It aims to foster accessibility in assessment by addressing the skills students need to access the content that is tested. UDA is mainly promoted as an approach to make the individual testing situations more accessible (see [28]).

In assessment, not all skills and knowledge are the intended targets of measurement, while other skills might influence students' ability to execute the tasks required to demonstrate mastery [29]. Ketterlin-Geller and colleagues conceptualised these skills as *access skills*, that can be organised into three categories: (1) *physical skills* that influence students' physical access to assessment (e.g., writing responses to test items), (2) *perceptual skills* that influence students' ability to see, hear or attend to the assessment situation (e.g., font size), and (3) *content skills* that consist of content that is taken as a prerequisite for the content being learnt (e.g., the addition of real numbers while solving linear equations). From the viewpoint of access skills, promoting UDA would mean considering as many access skills as possible and designing assessment that would reduce the need for them.

2.1.3. Is Universal Design effective?

Four recent literature reviews have shed light on whether UD implementations are effective in higher education. Here, we briefly report on both their findings and how these studies conceptualised effectiveness or impact.

First, Roberts and colleagues [30] conducted a systematic review on Universal Design for Instruction (UDI) and UDL, leading up to identifying eight research articles in the field. What they found was that the studies were not conducted in a systematic way, and that the methodology for grasping the effectiveness of UDI and UDL had been limited. It is concluded that there is a need to 'apply the operationalized principles of UDI in intervention studies to investigate the impact on objective student outcome measures' (p. 14).

Rao, Ok and Bryant [31] utilised a descriptive review method to investigate the empirical studies on UDI and UDL, finding five higher educational studies. Their conclusion mirrors that of Roberts et al. (2011); they stated that the studies on UD are not properly designed for examining whether the interventions have '*caused* improved learner outcomes in terms of content and/or skill acquisition' (p. 164; italics in the original).

Seok, DaCosta and Hodges [32] conducted a systematic review of 17 articles on UDL at the postsecondary level to find out that these practices were effective for both students 'with and without disabilities', based on many factors such as learning outcomes. Their results support the idea that active teaching methods, aligned with the principles of UDL, support learning. Furthermore, what was found was that all students, whether or not disabled, benefited from the practices.

Finally, Schreffler and colleagues [11] sought out quantitative and mixed methods studies in their systematic literature review on the 'impact' of UDL practices in postsecondary STEM education. They identified four articles, three of which involved students. In these studies, quantitative measurements regarding grade point average (GPA), test scores and various scientific instruments were used to conceptualise effectiveness. Once again, there was a call for more systematic quantitative research, in contrast with those 'many studies' that 'qualitatively examined the perspectives of the students' (p. 8).

Overall, it can be concluded that there has been a call for a more adequate methodology to analyse the impact of the UD implementations on learning results in higher education. According to the four literature reviews referred to here, this kind of methodology should draw on quantitative measurements such as test scores or GPA, with one review [11] stating that this would develop a field that had earlier been based on qualitative studies on student perceptions.

2.1.4. Student Perceptions of Universal Design

Research on student perceptions concerning UD appears to be scarce. Even though it has been stated that qualitative studies regarding these experiences would be common [11], we were able to locate few of them. Studies have mainly observed the accessibility of course designs utilising UD by neglecting the perspective of disabled students (see e.g., [33]). It is noteworthy that the chapter concerning students' reflections of UD in Sheryl Burgstahler's influential Universal Design for Higher Education [20] contains no scholarly literature such as journal articles.

The few studies we identified did not directly concern students' perceptions of studying in university courses conducted with the principles of UDL/UDI. Kennette and Wilson [34] surveyed disabled students about their experiences of whether the UD principles had promoted their learning during their studies. The overall results were positive; the authors noted that future research should find out whether these positive experiences correlate with course grades. However, it is unclear whether the courses in this study were conducted with UDL principles. Another study [35] examined whether disabled students taught through traditional models, and not through UD implementations, would benefit from UD practices. This study underlines the importance of individual affordances, since 'it is almost impossible to achieve a curriculum that tackles the needs of all learners without the co-occurring generation of barriers' (p. 1644). Therefore, the authors suggest that UD implementations should not be based on 'one-size-fit-all' approaches but also draw on flexible adjustments. Finally, Black and colleagues [36] interviewed disabled students about their perceptions of their studies. The UDL/UDI framework was used to analyse the data. It is concluded that UD would help reduce barriers for these students. Once again it is unclear how many UD practices the students encountered in their studies, as the authors only state that 'implementation of UD principles is still in its initial phases' (p. 6).

There seems to be a research gap in conceptualising the effectiveness of UD implementations by considering the voice of the ones who might need it the most—the disabled students themselves. We argue that even though the literature reviews on UD implementations in higher education call for more systematic (and preferably quantitative) methods for measuring their effectiveness, this essential perspective of disabled students' perceptions has been lacking in the literature and needs to be addressed. Here, we observed the perceptions of students in the context of undergraduate mathematics education, in which similar research barely exists.

2.2. The Objective of Study 1

In Study 1, we examined the perceptions of three disabled students who were students in an undergraduate mathematics course that utilised both UDL and UDA. Based on interview data, we investigated how these students perceived the accessibility of a Universally Designed mathematics course. Was the course design *effective* in terms of accessibility? The research questions were stated as follows: Utilising the frameworks of UDL [22–24] and UDA [27], what barriers and opportunities did disabled students experience while studying in a Universally Designed mathematics course? What access skills did the students need in order to access the assessment methods, and what access skills were not needed because of the course model?

2.3. Methods

2.3.1. Context of the Study

We want to highlight the importance of the Finnish context in which the study was conducted. The legislation in Finland offers various services for disabled university students. The Non-Discrimination Act (1324/2014) [37] provides a legal basis for students to gain access to 'reasonable adjustments', offered by higher educational institutions (15 §). Furthermore, according to the Universities Act (558/2009) [38], every student has the right to a 'safe learning environment' that does not 'hinder progress during their study' (41a§). More precisely, universities have the power to adopt rules and regulations that aim to build a 'pleasant university community' by 'including provisions on practical arrangements'. Thus, universities have a lot of autonomy in deciding how to deal with supporting disabled students. The Finnish Universities Act [38] provides academic freedom for teachers in their teaching and assessment methods. In short, conducting a course model that comprehensively utilised the principles of both UDL and UDA was possible in our context.

2.3.2. The UDL/UDA Design

The study was conducted in the Digital Self-Assessment (DISA) project at the University of Helsinki. In this project, a digital Moodle environment for self-assessment was created in the context of large classes. The DISA course model was utilised in a 5-credit point proof-based undergraduate linear algebra mathematics course that lasted for seven weeks. This large course is typically one of the first that mathematics students take, but it is also largely taken by students majoring in other subjects. The topics covered include matrix computations and vector spaces. Of the 426 participants who were enrolled in the course at the beginning, 313 actively engaged and passed it. It was possible for the students to study the course completely online. The course was graded on a scale from 0 ('fail') to 5. Following a request by Rao and colleagues [31], we carefully opened the DISA course design utilising the principles of UDL and UDA. The summary of how the different elements of the course reflected the principles of UDL [23] is shown in Table 2.

Overall, the teaching of the course was designed to be student-centred. Teaching was based on the student-centred Extreme Apprenticeship Model which is a form of flipped learning [39]. The lectures were active and interactive, and the teacher utilised both discussions and digital polls. Student tutors were hired to offer guidance in an open learning space, and students were encouraged to study there. This space was open every day and offered a venue for peer interaction and feedback rather than just focusing on being a support centre for mathematics tasks. The tutors were trained for their job by offering them tools to teach mathematics and to provide constructive feedback and scaffolding (for more about the open learning space see [39]).

Table 2. The implementation of the UDL principles in the course design.

Principle 1: Representation		
Options for Perception	**Options for Language, Mathematical Expressions and Symbols**	**Options for Comprehension**
Digital learning environment Course material designed by the instructor Dynamic geometry tasks offering multiple representations	Materials in Finnish and Swedish Mathematical discussion and writing as learning objectives in the rubric A guide for producing mathematical text was provided	Structured content and scaffolded weekly tasks Concept map tasks about the relationships of concepts Digital tasks for revising the content in the end of the course Authentic, applied mathematical tasks related to e.g., computer science and physics Programming tasks
Principle 2: Expression and Action		
Options for Physical Action	**Options for Expression and Communication**	**Options for Executive Functions**
Support from the student tutors to use the digital tools Opportunity to study completely online	Digital rooms and forums for group discussions Anonymous discussion forum Digital polls during lectures Every student had their own student tutor Various sources for feedback: automatic feedback, feedback from the teacher, student tutors, peers and yourself	Feedback from the self-assessment tasks to promote self-regulation Digital tasks and automatic feedback whenever needed (Stack) Generic learning objectives (e.g., 'reading and writing mathematics')
Principle 3: Engagement		
Options for Recruiting Interest	**Options for Sustaining Effort and Persistence**	**Options for Self-Regulation**
An open learning space with student tutors and peers offering support when needed Summative self-assessment; students set their own course grades [14]	Acceptive and supportive classroom climate Active lectures based on discussion; minimising the social demands Formative assessment used to value process and effort Feedback on the weekly mathematics tasks and a chance to revise them	The course rubric with exemplars provided in the beginning of the course Formative peer-assessment tasks, of which feedback was offered Formative self-assessment and goal-setting tasks, of which feedback was offered Flipped classroom approach through Extreme Apprenticeship [39]

Several channels for digital interaction were offered through various digital applications. First, an anonymous discussion forum was used to gather feedback from the students. The students could also talk about the assignments in the anonymous discussion forum, if they wished not to reveal their name. Furthermore, voluntary student groups were conducted through a digital communication application, each led by one of the student tutors. These digital groups were used to foster social interaction, especially for those who were studying exclusively online. Moreover, the digital learning environment provided online forums for communication. Overall, the staff did their best to create a warm and welcoming atmosphere in the course.

The course utilised a detailed rubric that communicated the learning objectives in a clear way by providing exemplars. There were two sets of learning objectives: Content-specific and generic. Examples of the content-specific objectives are 'matrix computations' and 'solving linear equations', while the generic objectives involved objectives such as 'reading and writing mathematics'. Of the topics, five concerned mathematical content and four concerned generic skills. The criteria were given for grades 1–2, 3–4 and 5 (for details see [14]).

During the course, various forms of feedback were offered to the students. Feedback processes were based on the idea of feedback cycles; the students were given a chance to actively process feedback and act on it [40]. Three kinds of feedback were offered for the mathematical tasks. First, there were weekly digital tasks offering automatic constructive feedback (the Stack system; see [41]). In addition, there were two kinds of pen-and-paper tasks. The first set comprised two or three tasks concerning the most central mathematical concepts. One of these tasks was selected for further feedback that was provided by the student tutors. Students had an opportunity to return a revised solution twice. The second section of pen-and-paper assignments consisted of tasks for which no feedback was provided, but the model answers for these tasks were published later. Digital peer assessment of mathematical tasks was provided in the digital learning environment, and the digital feedback on students' peer assessments was based on how constructive they were.

Assessment in the course was conducted reflecting the UDA principles, aiming to reduce the need for all the possible access skills [28]. There was no final exam: it was replaced with summative self-assessment [14]. At the end of the course, students could decide how they would end up with a specific grade. During the course, students practiced self-assessment with two digital, formative self-assessment tasks. The rubric was used as a base for these tasks. Overall, the tasks were designed to foster reflection and self-regulation, and the students were encouraged to reflect in writing on their self-assessed marks for each of the learning objectives. Digital feedback on these tasks was based on the mathematics assignments that the students had completed during the course. The final marks were validated through the same digital system that offered the students digital feedback on their self-assessments. This was done to ensure that students with low self-efficacy would not assess themselves with a very low grade and to prevent obvious cheating.

2.3.3. Participants and Data Collection

All the participants were emailed an advertisement about the interview study. In the advertisement, it was stated that we were looking for students who had experienced challenges of any kind during their studies. Each student could decide how much they wanted to share about their challenges and medical condition, and this choice was respected. Six students participated in the study and self-identified as having learning difficulties. Three of these interviews were used as the dataset for the present study; these three interviews were chosen for the study since these students majored in STEM subjects. The data were collected after the course through semi-structured interviews by the first author. The questions concerned students' experiences of the various teaching and assessment methods of the course, as well as their challenges during the course. It is noteworthy that while signing up for the interview, all the students shared information about their condition, but the interview questions itself did not directly ask the students to discuss their disability status. It was made clear to the students that their perceptions mattered since the interviews would be used to develop the course model further. The duration of the interviews varied from 38 to 92 min. The interviews were audio taped and transcribed using discussion analytic coding.

The descriptive information about the participants is displayed in Table 3. Gender was not reported due to anonymity issues. Finnish gender-neutral pseudonyms were used in the study to refer to the students: Rusky, Lumi and Tyrsky. One of the students studied mathematics as their major subject, while two majored in other science disciplines (such as chemistry). All the students were under 24 years of age. It is notable that Tyrsky did not participate in the final self-assessment due to quitting the course before it ended. Therefore, only two of the participants completed the course.

'Disabled students' is the term used in this study to refer to the participants (see [42]) consisting of a diverse range of individual support needs. This choice of a term highlights the approach of the social model of disability about the environments *disabling* students. Our purpose is not to label these students as one group and contribute to constructing a discourse of 'disabled people' as one subject. Instead, our purpose was to highlight that usually these students are neglected in research concerning UD, and in the current study they were given a voice—even though mediated by the researchers.

Table 3. Participants of the study.

Name	Self-Identification	Major	Year of Study
Ruska	Dyslexia	Science	2
Lumi	ADHD	Mathematics	2
Tyrsky	Autism spectrum, Obsessive Compulsive Disorder (OCD)	Science	3

2.3.4. Analysis Methods

The analysis methods resembled those reported in Griful-Freixenet and colleagues' study [34] about student perceptions of the UDL framework. The data analysis was based on theory-guided qualitative content analysis [43]. First, the authors familiarised themselves with the transcript data by carefully reading it through several times and discussing the emerging themes. After this initial phase, the data were analysed using two theoretical frameworks. First, the data were read through the framework of UDL [23], and each of the relevant analysis units as defined by coherent sets of ideas [43] were coded under one of the nine UDL guidelines. After this, more data analysis followed, looking for the three types of access skills [28] based on students' perceptions about the assessment of the course. In this way we intended to get a consistent picture of the students' perceptions of accessibility of the teaching and the assessment methods. Both coding schemes contained a column for 'other', enabling the data-driven themes to emerge. Some analysis units related to more than one UDL/UDA principle, and some units were coded with the frameworks of both UDL and UDA. Earlier research has mentioned this as a natural part of the analysis regarding UD [35].

To ensure the trustworthiness of the current research, we utilized researcher triangulation [44] throughout the analysis. First, the corresponding author, who initially analysed the data, frequently discussed the emerging codes with the co-author. Second, the co-author independently analysed the data using the coding scheme based on the UDL and UDA frameworks, which was followed by a data validation meeting [45]. The codes were checked and discussed during the meeting until consensus was reached.

2.4. Findings

Each of the three interviews provided a personal perspective on the opportunities and challenges of the UDL and UDA implementations. First, we wanted to look for similarities between the students by contrasting the coding framework between each of the interviews. The interviews varied a lot, both in their length and content, but some similarities could still be drawn. It should be noted that some of the excerpts have been published before in a conference publication [46].

2.4.1. Similarities in the Interviews

Overall, UDL guideline 9 (Options for self-regulation) connected all three interviews. The students reported that the detailed rubric and the self-assessment practices had a positive impact on their learning and studying, since these elements allowed an opportunity to set goals and monitor one's own performance. The rubric allowed the students to divide their understanding of their own skills into smaller 'units', as Tyrsky put it. Ruska described the self-assessment tasks of the course by saying that 'self-assessment teaches me to observe what I really know'. Tyrsky continued by summing up how self-assessment teaches self-regulation skills by comparing the formative self-assessment tasks of the course with tracking one's sports results:

> Tyrsky: Through self-assessment you become more aware of the training in mathematics, because just like in any sport, you constantly need to track your own performance.
>
> * * *
>
> Tyrsky: When you need to assess your own performance, it helps you to understand which parts of your training program are clever. And what you have done lazily. So just like in any sport, tracking your own skills is a skill itself in mathematics too.

Concerns regarding the social aspect of learning during the course arose in all the interviews (UDL Guideline 5: Options for expression and communication). Each student described studying completely alone during the course. Ruska and Tyrsky described experiencing barriers with some of the digital, social tools of the course. Both described that the digital groups in the communication application were useless for their learning. To sum up, even though the students had negative experiences concerning accessibility of the digital elements of the course, each of them was thankful for the digital Moodle environment for ensuring that they could complete the course online by working alone. Next, findings from all three interviews are reported separately to highlight their unique elements.

2.4.2. Ruska

Ruska described benefiting from the overall course structure that allowed 'a certain logical structure, but without leading to chaos'. Of the UDL principles, it was Engagement that provided significant support. The rubric helped Ruska to set goals and prepare plans for reaching those: 'you could plan your work during your studying'. Furthermore, Ruska described how the peer-assessment practices were useful for learning. Ruska mainly studied by reading the course material individually and solving the mathematical assignments. Therefore, according to Ruska, the digital course material acted as the main support system during the course. Ruska described the options for comprehension (UDL Guideline 3), such as the scaffolded mathematics tasks and the digital GeoGebra tasks that visualised mathematical concepts, as being beneficial to their learning process. Ruska was also grateful for the language used during the course:

> Ruska: The plain language used during the course was extremely easy to understand. The language used in the instructions and in the assignments was carefully designed, and it made the learning environment more efficient. I don't have any complaints here.

Ruska described experiencing some challenges due to having dyslexia, especially in relation to the UDL principle 1 (Representation). Overall, the fact that all the course material was online caused troubles, since Ruska described a preference for always reading paper-based text. The digital materials with mathematical notations related to slowness and lack of resources throughout Ruska's interview. Even though Ruska understood the importance of the applied programming tasks that brought together linear algebra and programming, operating with the mathematical symbols in the programming environment took a lot of time. Moreover, it was not enough to learn the programming language for the programming tasks during the course, but the mathematical notations for the digital Stack assignments also needed to be mastered. Once again, for Ruska that meant more time for working:

> Ruska: It was so slow. If you look at how much it took me to work on the Stack assignments, it might say like three hours. It took so long, and I might have had no idea about what to do. I mean, how would I know, how the notation for power, I just tried something, and the system always showed an error.

Since there was no course exam, Ruska did not have to apply for any assessment adjustments. Therefore, the usual perceptual access skills were not needed. Ruska described that during the final self-assessment task, there was plenty of time to reflect on the learning. Nevertheless, there were some analysis units coded under 'other access skills' related to the socio-emotional aspect of self-assessment. Ruska explained about being very self-critical, which caused skills to be undermined in the self-assessment tasks. Since there was no final exam, the final confirmation of Ruska's skills and knowledge was missing:

> Ruska: I still believe that my capabilities are not as good as it says there. But it's just this self-criticism. If you'd give me one of the course assignments now, I don't think I could solve it.

2.4.3. Lumi

Lumi had tried to complete the same course in the previous year but did not pass it. This time Lumi was able not only to pass the course but to achieve the desired grade. For Lumi, one of the main aspects of accessibility was that the learning environment was warm and accepting (UDL Guideline 8: Providing options for sustaining effort and persistence). For example, Lumi thought that support was provided for any problems encountered during the course. Furthermore, according to Lumi, the teacher often highlighted that 'there are no stupid questions'. Lumi thought that the online learning option was part of addressing the needs of the diversity of students. Lumi pointed out that 'the fact that you can return the assignments online makes your life so much easier':

> Lumi: Maybe here in the mathematics department we can already be aware of the needs of people who don't necessarily want to participate in the lectures. Or any other occasions. It's good to consider those who do not learn like everyone else.

Lumi described having benefited from the various digital systems used in the course. The digital online material was the main support system while studying alone. Lumi described the material as being very clear and comprehensive. Lumi connected the GeoGebra assignments with a deeper conceptual understanding of mathematics (Guideline 3: Options for comprehension):

> Lumi: You just understand the concepts so much easier like this. Rather than just seeing some symbols on paper. In those situations, you don't really understand what's happening.

Interestingly, Lumi described overcoming barriers for learning by being able to 'archive' all their coursework on Moodle. Lumi 'massively benefited' from the course structure in Moodle that automatically arranged their assignment submissions according to their mathematical topics. This 'digital archive' was the backbone of Lumi's new, more organised way of studying (Guidelines 1 and 9: Options for perception and self-regulation):

> Lumi: It [the online Moodle environment] makes everything so much easier. For example, if I want to look at some of my old assignments, I don't have to look for a pile of paper, but I'll just check them directly from Moodle. It's so much easier to archive everything in a digital form.

Lumi often connected ADHD diagnosis with challenges that the course design evoked. Barriers to learning were identified, especially in terms of UDL guidelines 1 and 4 (options for perceptions and for physical action). Lumi appreciated many of the social elements of the course but thought that their general structure meant it was not possible to benefit from these. The following excerpts about both the lectures and the open learning space highlight the reason why Lumi described working alone as the only way to study: working alone causes no distractions.

> Lumi: I did visit one of the lectures. And the lecturer is a very good one. It's just that the structure of the lectures is not good for me at all. There's too much noise, and a lot of visual stimuli. People move around all the time. I can't control my own focus, and it just wanders towards where there is the most hassle.

> Lumi: About the open learning space. I didn't work on any assignments there. I feel that I learn the best wherever there is as little distraction as possible. And that kind of a hallway where people just go to and fro... Well, I just thought that maybe it's better to just be in front of my own desk, at ease.

Usually Lumi might have needed a personal space for the examination, but in this course there was no need for that. This account was coded as a perceptual access skill that was now not needed. In terms of assessment, Lumi described benefiting greatly from the various feedback processes during the course. For example, it was possible to develop the work through digital peer-feedback (UDL Guideline 6: Options for executive functions). Furthermore, the feedback provided by the student tutors helped in elaborating mathematical solutions. However, the final summative self-assessment related to uncertainty about one's own skills by Lumi. Like Ruska, in the end Lumi was not completely sure about the level of mathematical understanding, even after reflecting on the learning based on the rubric. Lumi described being very 'unsure' whether self-assessment was possible, calling for an additional exam that would have confirmed one's skills:

> Lumi: I think it [summative self-assessment] was insufficient because it's a bit hard to show your skills by assessing yourself. That's why I think the best system would include an exam in addition to self-assessment. Just because someone might constantly overestimate or underestimate one's skills.

2.4.4. Tyrsky

As noted, Tyrsky described benefiting hugely from the self-assessment process, since it was possible to monitor self-learning and studying in an analytical way. Tyrsky described this as 'a very pedagogical experience'. Tyrsky also made great use of the various options for comprehension (UDL Guideline 3). According to Tyrsky, the digital tasks were optimal for 'revising content', the GeoGebra tasks contributed to a greater conceptual understanding of mathematics and the programming tasks were a 'powerful tool for matrix computations'. Tyrsky praised the plain language used throughout the course in each of its instructions (UDL Guideline 2: Options for language).

Tyrsky's story differed from those of the other students, since Tyrsky quit the course before it ended. When asked about the whole assessment process of the course, Tyrsky noted that it did not cause any barriers, but the overall course arrangement did. Tyrsky described that the course structure resulted in a lot of stress and anxiety, leading to 'finally admiting that I can't handle this anymore'. Because the course consisted of so many components (see Table 2), Tyrsky had to feel 'constant pain'.

> Tyrsky: The frustration caused by any of the individual assignments cannot be compared to the feeling of frustration that the number of compulsory assignments caused. You have to complete them all, and they all contribute marginally to the grade. That really made me feel disempowered.

Tyrsky often referred to 'energy' and how certain actions reduced the amount of it. Regulating one's studying and remembering all the deadlines of the course were connected by Tyrsky to 'reduced level of energy'. Furthermore, the social elements of the course demanded a lot of self-regulation and initiative-taking, once again connected with the idea of an 'energy bar'. Even though Tyrsky understood the importance of the open learning space for self-learning, attending the space demanded extra energy:

> Tyrsky: After attending a lecture you don't have enough energy to go there and to wave your arm to find a teacher to help you.
>
> * * *
>
> Tyrsky: I didn't have energy for that hassle. You must take the social initiative. In a way, you must be responsible for yourself.

Many of Tyrsky's accounts were coded under the UDL Principle 2 (Representation) because of the challenges Lumi had with digital systems and devices. Tyrsky explained that showing skills and knowledge in the digital Stack assignments was not possible because of the complex and 'unclear' syntax in the assignments. Tyrsky had to find someone to help with the digital submissions every week—this process Tyrsky described as 'painful'.

2.5. Discussion

Utilising the frameworks of UDL [22–24] and UDA [27], we investigated the opportunities and challenges for accessibility that the DISA course model offered to three disabled students in an undergraduate mathematics course. Each of the interviews offered a unique perspective on accessibility, highlighting the importance of considering student perceptions while inclusive learning environments are designed (see [35]). Moreover, our results call for further research on the accessibility of modern mathematical learning environments that have been advocated in recent literature [6]. Each of the three principles of UDL created both opportunities and challenges for these students. For example, we noted that the digital elements of the course caused learning barriers for both Ruska and Tyrsky. At the same time, the online environment enabled Lumi to organise studying through a 'digital archive'. We also gained important information about the accessibility of open learning space in university mathematics that supplements the earlier literature [6,39]. We encourage researchers and practitioners to hear the perceptions of the disabled students whenever the effectiveness of a UD design is examined in education. Here, these three interviews provided a new perspective on our course design compared to our previous quantitative study [14].

Our results underline the importance of being aware of the role of assessment while designing for accessible learning environments. All three students described how they benefited from engaging in the self-assessment process. We propose that promoting UDA is especially important in the exam-driven assessment culture of undergraduate mathematics [7,8]. Here, summative self-assessment was utilised to consider many access skills related to assessment during the actual design process and not just retrospectively. For example, Ruska and Lumi did not have to apply for any of the special arrangements that they would usually have needed. Interestingly, we identified many barriers in the 'other' category of access skills. These accounts of barriers were related to socio-emotional factors, as could be seen in Ruska's description of how Ruska systematically tended to underestimate their own skills. We argue that the socio-emotional aspects of learning need to be considered while designing for accessible assessment in mathematics. For example, it is interesting that many of the students hoped to have an exam to confirm the level of their skills and knowledge, which reflects the earlier literature [8]. Our results underline the importance of supporting and scaffolding self-regulation in student-centred learning environments that demand a new kind of a responsibility over one's own learning and studying. This was seen the most clearly in the case of Tyrsky, who had to quit the course because of its fragmented structure.

The barriers faced by the three students participating in this study are obviously not only specific to disabled students. Nevertheless, our study aims to break the critical silence in university mathematics and give voice to this specific group of students (see [1]). But was our approach enough to frame these students as 'doers and thinkers of mathematics' [3]? In summary, Study 1 helped us to consider various new viewpoints on accessibility while designing for accessible learning environments in mathematics. However, we could not help but notice how all three students described the studying process as being lonely. Furthermore, the students seemed to distance themselves consciously from the overall student population. To understand this issue further, we needed to plunge back into the literature to find a conceptual tool to capture these issues. Next, the concept of mathematical identifying is introduced and observed in Study 2.

3. Study 2: Students' Identifying Narratives

3.1. Theoretical Background: Constructing Identities in Postsecondary Mathematics

Earlier research on undergraduate mathematics has underlined the importance of pedagogical practices to students' identity development [47,48]. For example, even though not directly addressing disabled students, Solomon [47] calls for accessible pedagogy that would encourage 'the exploration, negotiation and ownership of knowledge, and the development of a corresponding identity of participation' (p. 93). Elsewhere, mathematical teaching practices based on rote learning have been linked to alienation and disengagement [48], highlighting the impact of the learning environments on students' sense of themselves as learners. Would Universal Design offer a way to challenge the 'dominant discourses' [47] (p. 93) of university mathematics education, and provide a chance to build identities based on inclusion?

To understand the interaction between Universal Design and students' identities, we draw on earlier mathematics educational research by taking a discursive perspective on the concept. Through that perspective, we do not conceptualise identity as a static construct but as something that is constantly constructed in active narratives [49,50]. We especially lean on the concepts of subjectifying and identifying [51]. *Subjectifying* refers to any communication about the participants of mathematical discourses (rather than mathematical discourse itself), while identifying is the 'activity of talking about properties of persons rather than about what the persons do' (p. 2). Following Sfard and Prusak [49], we parallelise identity-building with story-telling, defining *identifying narratives* as 'narratives about individuals that are reifying, endorsable, and significant' (p. 16). Therefore, even though we utilised a discursive framework, we did not see identity as an ever-changing positioning (see [50]) but as a relatively stable concept that can be reified and that is significant to the students themselves (see [50]).

Heyd-Metzyanim [52] studied the co-construction of mathematical learning disabilities through the notion of identifying narratives and argued that constructs such as 'dyscalculia' might be *products* of learning environments (see also [9]). This idea largely reflects the social model of disability [18,19]. Learning environments might contribute to students' relatively stable identifying narratives about their position in relation to other students. We conceptualised identifying processes utilising three levels for verbal, direct identifying narratives [51,52] as summarised in Table 4.

Table 4. A typology of identifying narratives and examples of the data [48,49].

1st level: Subjectifying about specific performance	**2nd level:** Subjectifying through general evaluations	**3rd level:** Subjectifying by attributing properties or assigning membership
	Key words: always, never	**Key words:** be, have
'I did not know how to solve the task'	'I never succeed in matrix computations'	'I am dyslexic'
'I underestimated myself in mathematical self-assessment'	'I always make a lot of mistakes'	'My ADHD brain . . . '

Even though Universal Design has often been linked with the social model of disability [18], the notion of identity has been largely neglected in relation to it. For example, Couillard and Higbee [53] observed how the scope of UD could be expanded to consider the identity-building processes of various non-binary gender identities and sexual orientations, opening an important field of higher educational research. The authors used the concept of intersectionality to highlight that rather than having a single identity, students have many unique intersectional identities. However, to the authors' knowledge, studies concentrating specifically on UD and identities have not been conducted in the field of disability studies. This forms an obvious research gap that we wish to fill through Study 2.

3.2. Objective of Study 2

To supplement Study 1, the aim of Study 2 was to shed light on how the students narrated their learning disabilities during the course. Utilising the discursive concept of identifying narratives, we asked whether the UDL/UDA design would have been able to affect these students' identifying narratives related to their learning disabilities. The research question was formulated as follows: What identifying processes did the students construct in their interviews in relation to their learning disabilities?

3.3. Methods

Analysis Methods

The analysis started by extracting identifying activities from other talk and stories that the students had (see [52]). After that, those identifying narratives were selected for further analysis that were, following Sfard and Prusak [49], reifying (students talking about how they *are* rather than what they *do*), endorsable ('the identity-builder, when asked, would say that it faithfully reflects the state of affairs in world', p. 16) and significant (the narrative has to be significant to the storyteller).

Since our study involved interviews with university students, we focused on analysing verbal and direct identifying narratives [51,52]. Indirect identifying narratives were coded only if they clearly contributed to the overall identity narrative of a specific student. Non-verbal subjectifying actions were coded in extreme cases, since the analytic coding of the transcript only coded emotional cues such as laughter and long breaks. Furthermore, 1st level subjectifying actions were considered to be identity narratives if they consistently built towards a coherent picture of one's self (see [51]). Finally, an overall understanding of the content of each of the identifying narratives was opened. The trustworthiness of this analysis was ensured by using the same methods as in Study 1.

3.4. Findings

3.4.1. Ruska

As noted in Study 1, Ruska connected the barriers constructed by the learning environments with their dyslexia. Indeed, Ruska's accounts about their 'slowness' thoroughly characterised the interview. The analysis mostly found 3rd level identifying narratives connected to Ruska's dyslexia: Ruska clearly saw that as a defining feature as a learner. Dyslexia was constructed as a biological state which created barriers that could not be overcome by pedagogical support mechanisms.

> Ruska: It would always be nice to get some support for dyslexia. Which means more hours to a day, but that just isn't possible.

Ruska directly talked about dyslexia but never referred to being 'dyslexic' or 'having dyslexia'. Rather, the 3rd level identifying narratives consisted of stories about being slow. It is notable that Ruska did not build a narrative upon phrases like 'I am always so slow', which would have indicated 2nd level identifying activities. Rather, Ruska reported *being* slow and described that slowness having a great effect on overall studying. This can be seen in the way Ruska reported studying alone because of 'progressing slowly':

> Ruska: I have always worked alone. The biggest thing is that if I'm working on exercise number one, and everyone else has started that task at the same time as me, they already

> move on to the exercise five while I'm moving on to the exercise two. I just progress so much slower. For a long time, I've thought that it's better for me to work alone.

> Ruska: When working in a group, I feel an enormous amount of group pressure. Just try to write down your answers at the same pace as everyone else, you just can't succeed in that! I've been to small groups or whatever, you know, where you need to work in groups with other students. These kinds of situations are always very difficult for me since, I mean, goodness. You must write so fast, you just write down whatever comes to your mind first. And the answers to those tasks, they are what they are.

The accessibility of the digital elements of the course was a major theme in Ruska's interview, and this can also be seen in the identifying narratives. Third level narratives were identified when Ruska described *dyslexia* causing troubles with technology, especially when it came to reading mathematical text from the computer screen.

> Ruska: It would have been nice to have the material as a physical copy, rather than reading it from the screen of my computer. I read even more slowly from the screen because of the background light. I get so confused about the line that I'm reading. With a physical copy it's so much easier to follow. I could have printed that. But that cost a lot of money, so no thank you.

The frustration about technology was seen in some 2nd level identifying narratives, such as in Ruska's description concerning irritation about technology: 'I am always the one with technical issues with all the devices!' According to Ruska, dyslexics' own preference was to write with pen and paper. These 2nd level identifying processes were closely tied to the 3rd level narratives about Ruska's slowness. Ruska went as far as thinking about whether studying mathematics would be possible if more online tasks were to be introduced:

> Ruska: If these assignments are going shift into online assignments, I'm going to quit doing mathematics completely. Because I just couldn't handle it. It takes too much time. I need to work for like one day to be able to write down all these mathematical symbols for one assignment.

Interestingly, 1st level narratives were only identified in terms of assessment in the course. Otherwise Ruska talked about slowness as a defining feature, but when describing experiences with mathematics examinations, 1st level identifying narratives were seen:

> Ruska: I didn't need it [extra time in the exam] now. If there would have been an exam, I don't know if I would have needed extra time. I don't usually have time to read and write all the answers. It depends completely on the exam, I didn't check what kind of an exam this course had. If the questions are easy, the normal time might have been enough. But now I don't need it, since I took part in self-assessment.

3.4.2. Lumi

Lumi's accounts related to learning disabilities during the course almost exclusively consisted of 3rd level identifying narratives. Even though the interview questions never directly asked about the status of the students' learning difficulties, Lumi constantly brought it up. Lumi referred to 'using medical language', such as referring to themselves as an 'ADHD person'. These accounts, especially when they related to medical or neurological concepts, were identified as clear examples of 3rd level identifying narratives:

> Lumi: What I did was that I started to work on the assignments on the last day before the deadline. It worked well for me. I think everyone who has a brain like mine says that it is a very good motivator to feel a sense of hurry. Some even say that it's compulsive, that it brings some posture to your studying.

This narrative was surely constructed way before this specific course. This became evident in the narrative about Lumi's first year at the university. Lumi described how in the last year, it was necessary to develop a unique 'learning strategy' because it was not possible to study 'like other people':

> Lumi: Last year, when I started my studies, I basically failed the entire year. The reason is exactly because I tried to study just like everyone else is studying. By the end of the year I realised that I hadn't even received grades from my courses.
>
> * * *
>
> Lumi: So last year I had a feeling that gosh, I can't be helped. But then I developed my own learning strategy. Okay, maybe I don't learn like other people. Maybe I need to learn in my own special way.

Lumi described using a personal learning strategy during this course as well. The course design offered a lot of different elements to support learning and studying, but these did not fit Lumi's 'learning strategy'. Instead, Lumi had designed a study method based on using timers. It is notable how Lumi's identifying narratives would always use first person language, which was underlined when describing the *special* study method.

> Lumi: I used a timer the whole time. For example, I decided that I'll start working at five o'clock. And after that I didn't do anything else before completing the tasks. The most important thing is that by using a timer you reach a certain kind of regularity to your studying. That's the best thing.

> Lumi: So, I built my own learning style. Okay, I don't attend any lectures, but I'll complete all the tasks by myself. Maybe this'll work.

> Lumi: I'd say that the university still assumes that you'd learn in some specific ways. But you can't assume that everyone would learn in a similar kind of way. For some people sitting at the lectures is a waste of time. It's a waste of time for me. (laughs) I would rather read the material at home.

Interestingly, even when Lumi was sharing views about accessible environments and course designs, the 3rd person identifying narrative about being a special kind of a learner was used. Lumi was thankful that learning environments had been developed during recent years in the mathematics department but was excluded from the group of people who would be able to benefit They constructed an image of from those environments. For example, Lumi thought that the open learning space was 'not for people like me', describing the situation with medical terms such as 'stimuli' and 'symptoms'. The same identifying narrative was seen when Lumi was giving positive feedback about accessible learning environments:

> Lumi: I think it's very good that teachers want to map out the needs of the different kinds of learners.

> Lumi: This year many courses have been modernised. There are, for example, digital submissions for tasks. Those kinds of things take into account my situation as well. It's good that you consider those people who do not learn like everyone else.

3.4.3. Tyrsky

Tyrsky's identifying narratives differed from the others since they never directly referred to autism spectrum disorder or to OCD. Tyrsky only shared information about their condition before the interview with the first author, stating that they would have needed more support for these conditions.

However, in the interview, these words were never used. Tyrsky only mentioned quitting the course because it caused 'a lot of stress especially for me because of my personality'.

Instead of referring to learning disabilities, Tyrsky's identifying narratives were based on two major themes, both coded as 3rd level identity narratives. First, Tyrsky self-referred as a 'Luddite' and elaborated that further:

> Tyrsky: I am someone who actively tries to dissociate myself from the technological framework.

Tyrsky did not own a smartphone and constantly referred to a personal dislike of technology. What helped us to identify these accounts as part of a 3rd level identifying narrative was the language used by Tyrsky. Rather than claiming 'always wanting to avoid technology', Tyrsky used extreme medical terms such as 'pain' and 'torture' to highlight being a person who cannot participate in digital learning.

> Tyrsky: A lot of internet means a lot of time spent at the computer, which for me is just awful torture. For example, reading the course material from the screen of your computer is horrible torture for my eyes and I need to do that for hours.

The other 3rd level identifying narrative that could be observed throughout Tyrsky's interview was linked with the fragmented nature of the course design. During Study 1, it was interpreted that the course design caused barriers for Tyrsky's studying. A closer look into Tyrsky's identifying activities revealed that they actively constructed a 3rd person narrative about *being* a person who needs clear structures. Tyrsky described feeling 'constant, weekly, mental pain' during the course because of its structure. Tyrsky even blamed the course for causing psychological harm in the longer term.

> Tyrsky: I was completing these tasks while feeling a general nervousness and anxiousness because of the vast number of different types of tasks. And because of the digital submissions for the tasks. They are understandable when you think about the course in general but challenging from my perspective.
>
> * * *
>
> Tyrsky: While I was finishing up the mathematics tasks, I tried to motivate myself to suffer this cancer that I had in my calendar every week.

The analysis confirmed that Tyrsky's identifying activities built a stable narrative as a learner, and that this course design was a complete 'personality and life situation' mismatch. In the interview situation, the interviewer asked Tyrsky to describe how the course model could be modified to 'align with how you learn' better. Tyrsky's answer was coded as a part of the 3rd level identifying narrative about being substantially different from other students, since suitable educational environments could not be designed:

> Tyrsky: That's a tricky question since if I just think about how I would want the teaching to be arranged, what would be the best for me, that would be just me sitting and studying at home by myself. And when I would be ready, I would just say that now I have mastered this content. But I do realise that there are rational values in education that you need somehow to verify that you've actually learnt. So obviously teaching couldn't just happen at my home.

When and how had Tyrsky developed these solid narratives as a learner? Tyrsky constructed a longer narrative, stating that not participating in the advanced mathematics lectures at high school due to not 'completing a large number of tasks'. After that Tyrsky noted that 'it seems to be a recurrent theme in my life that if there are a large number of small tasks, I can't be bothered to work on those' and laughed. Finally, Tyrsky indirectly identified themselves as a rather unmotivated learner of mathematics:

> Tyrsky: Maybe a more motivated and proactive individual could have survived this [the course structure]. With less effort. But it is not that easy for everyone. Especially if you don't have the time or the energy.

3.5. Discussion

Study 2 observed the identifying narratives [51,52] that the students constructed in relation to their learning disabilities while they were recreating their experiences about studying in the Universally Designed course. What we noted was that all three students mainly constructed 3rd level identifying narratives about their learning disabilities. Ruska's narratives were based on dyslexia and especially slowness, Lumi's on biological and neurological differences and Tyrsky's on a unique way of studying. The 3rd level identifying narratives were based on deep assumptions about the students' personal attributes, and the 2nd and 1st level narratives were often coded to support these larger narratives. These narratives were seen in action as the students reconstructed their study methods in their interviews: all three studied alone and attributed this to their 'special' features. It can be summarised that the students were actively constructing identifying narratives that excluded them from the 'other students', as noted by Ruska. This notion closely reminds those of 'alienation' [48] and 'otherness' [46] as proposed in previous literature.

Even though Study 2 conceptualised identity as an ever-changing and dynamic construct [50], the narratives we identified painted a picture of learning disabilities as static, medical constructs. It is obvious that these narratives had already been formed before this specific mathematics course. At the same time, it is evident that the course design was not able to challenge the 'dominant discourses' of disabilities [47] (p. 93)—or, as Lambert [10] called them, the 'deficit mythodologies'. As a matter of fact, it might be that the course design further strengthened the 3rd level identifying narratives. Ruska and Lumi described being able to study alone in a way that fits their needs. For example, Lumi was now able to apply a 'special learning strategy' to study. Tyrsky, on the other hand, seemed to have strengthened an already stable concept about the needs as a learner. We argue that if a UD implementation would truly like to be aligned with the social model of disability, it should do its best to lessen the identifying narratives based on deficit-driven 3rd level identifying, drawing on medical and cognitive narratives. At the very least, UD should be able to tackle the construction of further identifying narratives based on alienation and otherness. It seems that the course model was not able to do this and might even have contributed to constructing the learning disabilities themselves (see [52]).

It should be noted that it was the researchers who reported the narratives in this study rather than the students. Therefore, the students' voice is largely mediated through our own voice. Indeed, the lack of a participatory approach is a clear limitation of Study 2. Furthermore, here we only approached identifying processes through interview data. Future studies could observe how identifying narratives are formed through actions within the higher educational learning environments (see [52]). We strongly recommend future research on postsecondary mathematics and disabilities to consider the notion of identity. More research is needed to theorise how elements of mathematical learning environments are interconnected to processes of identity construction (see [48,49]). Overall, we call for more research applying the previous frameworks on identifying [49,51,52] reported in the literature concerning UD.

4. Conclusions

UD has been advocated as a way to address the needs of the diversity of learners in postsecondary STEM education [11], yet in the field of university mathematics research, its reported implementations are rare. Furthermore, it is the field of mathematics education especially that has been claimed to neglect the voice of the disabled students by only seeing them through their deficits [3,4,10]. Within this context, a course model for undergraduate mathematics was designed through the principles of both UDL and UDA. The UD implementation was arguably impressive, as the assessment practices were also completely re-designed inclusively. Quantitative results on the effectiveness of the course design were no less impressive: the students in the course achieved highly and reported using study methods based on deep approaches to learning [14].

In the present article, we probed deeper into the data patterns and critically observed the UD implementation through the perceptions of three disabled university students. Study 1 addressed a research gap in the field of higher education, observing how these students perceived accessibility during the course. However, it was the results of Study 2 that we found to be provoking. While offering various important perspectives on accessibility in Study 1, in Study 2 the students framed their learning disabilities mainly through static and medical 'deficit mythodologies' [10]. We propose that part of what caused these results was the lack of a participatory approach, both in this study but also in the design process of UDL/UDA implementation. Even though many issues of accessibility were tackled for the course, it did not offer these students a chance to challenge their already constructed identifying narratives based on the idea of medical deficits. Opening up the design and also the research processes to these students might offer a way to shake up the dominant discourses. Furthermore, by developing the accessibility of many of the elements of this specific course design (e.g., the open learning space, the digital assignments) based on the results of Studies 1 and 2, we hope that in the future, the course design could offer more opportunities for developing inclusive identifying narratives *for everyone*. We note that our aim is not to frame the participants in this study only as 'disabled students', abridging the identities of these students into this concept. However, we do wish to bring forward the perceptions of this specific (yet obviously loosely defined) group of students that often gets neglected in mathematics, in higher education and in their intersection.

Based on our results, we argue that in order to widen access in higher education, Universal Design needs to be taken back to its roots and reconnected with the social model of disability. It says a lot that while the notion of UD arises from the field of accessible architecture [20] and has been widely connected with the social model of disability [18], perceptions of the disabled students have largely been unheard while implementing UD practices in education. We argue that by only conceptualising UD as a way to foster 'learning results' (or, in other words, grades or GPA) it might serve as just another mechanism to internalise learning into a medical and individual concept, thus reflecting the neoliberal ethos of contemporary higher education. This medical discourse is further validated by tying UD into 'brain networks' [23]. Does the recent literature on UD, based on these kinds of discourses and quantitative measurements, further validate the medical model of disability? Drawing on the medical model of disability might be the reason why the literature on UDL so rarely covers the topic of assessment, and why the literature on UDA almost exclusively deals with designing more accessible test items rather than completely redesigning assessment aiming to be *inclusive for everyone*.

Reconnecting UD with the social model of disability calls for further theoretical understanding of accessible learning environments. Earlier it had been noted that no learning environment is completely accessible to every single student [35]. We argue that this statement, often used both in research and practice, is not enough to theorise accessible environments and their interplay with the construction of disabilities [46,52]. As shown here, approaching UD through the perspective of the social model of disability offered a lens through which to conceptualise how the identifying narratives of the students were constructed within the course design. This approach might offer an interesting viewpoint for future studies on UD to supplement the positivist view that students would 'have' disabilities when they enter the learning environment. We argue that the notion of students' identity needs to be considered if UD is to be reconnected with the social model of disability. Furthermore, we note that this is especially crucial in the context of mathematics where strong deficit mythodologies have been identified [10]. Reframing UD as a set of practices—the purpose of which is to *include* rather than to boost learning results—means that there is a need to develop ways of measuring inclusion other than test scores. As was seen in our study, designing a learning environment that neglects the perspective of identity construction might end up producing students who are highly capable of doing mathematics but only from the position of the excluded.

5. Implications for Practice

Working in the field of disability studies, a measure of the impact of our study is whether it has any practical implications. First, we recommend that university mathematics educators implement the principles of UD in their teaching. If this work could be conducted in an intersectional way, it might have an impact on the retention rates and dis/engagement of underrepresented student groups. As the exam-driven assessment culture of university mathematics is widely known and reported, it is highly recommended implementing UD not only through UDL but through UDA as well. Given that there is a strong link between assessment, learning and studying (see, e.g., [25]), Universally Designed learning environments that do not consider assessment might fall flat. Overall, we encourage university teachers to implement the principles of UD *comprehensively*. For example, introducing peer-assessment or clickers in a mathematics course might be pedagogically justifiable, but it hardly counts as 'Universal Design' (see [6] for holistic approaches for designing mathematical learning environments).

The perceptions of disabled students must be heard while designing, implementing and evaluating accessible learning environments in postsecondary mathematics. In the field of mathematics, and university mathematics in particular, a critical silence [1] already exists where disabled students should have been heard [3]. We call for practical solutions that allow these students to have their say. As the learning environments of university mathematics develop further away from the unilateral knowledge transfer models, a participatory approach in design cannot just mean a feedback form after a course. Previous literature in the field of higher education has provided a lot of information on co-designing learning environments with underrepresented student groups. It is time to bring that knowledge into mathematical lecture halls.

Finally, mathematics educators at the postsecondary level need to acknowledge that learning mathematics is not the only thing that is happening within our learning environments. Students also build their image of themselves as learners of mathematics—and if learning is to 'become someone' [49], this perspective should not be neglected. As shown in this study and as addressed in the previous literature, disabled students do not just enter mathematical learning environments with their innate deficits, but the disabilities themselves are constructed within those environments. If this sounds highly theoretical, close your eyes and think about the usual learning environment of university mathematics. Who designed it—and for whom? Does it enable opportunities for students to build narratives around belonging and being included? Does it see *all* the students as thinkers and doers of mathematics?

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